NATIONAL INVASIVE SPECIES COUNCIL

RESEARCH, INFORMATION SHARING, DOCUMENTATION AND MONITORING WORKING GROUP

[Version 6/15/00]

SCOPING STATEMENT

The Research, Information Sharing, Documentation and Monitoring Working Group has identified critical needs in the areas of research, monitoring and information management that provide the foundation for assessing the risks needed to make science-based decisions to prevent the introduction and limit the spread and impacts of non-native invasive species (NIS). Activities in any of these areas should emphasize place-based data including international sources.

Our approach includes multiple elements designed to address fundamental questions about research, information, documentation, and monitoring, and other questions concerning NIS.

1) **What do we need to know?**
   - Identify core knowledge for an effective national response to invasive species. Include an understanding of the biology and impact of invasions and attributes of vulnerable species, communities and ecosystems; consider of information characteristics with respect to spatial and temporal scales of measurements, taxonomic identification, biological attributes, detection and impacts.
   - Prioritize these knowledge needs to the extent possible.

2) **How do we obtain this knowledge?**
   - Characterize the existing capacity to provide core knowledge, identifying key gaps and limitations.
   - Identify research and monitoring that address real needs, fill key information gaps, and address limitations.

3) **How do we make the resulting information most accessible for the necessary policy, management, science and public uses?**
   - Characterize the existing structure, management and accessibility of information on NIS across ecosystems and taxonomic groups, identifying the current merits and limitations.
   - Identify and evaluate strategies, especially in the area of database development and access, to address existing needs.
   - Foster the integration of knowledge for management and evaluation of risk.

EXECUTIVE SUMMARY

The Research, Information Sharing, Documentation and Monitoring Working Group has identified critical needs in the areas of research, monitoring and information management that provide the foundation for assessing the risks and making science-based decisions to prevent the

introduction and limit the spread and impacts of non-native invasive species (NIS). We have recommended that activities be placed-based and that they address the following questions:

1) What do we need to know, 2) How do we obtain this knowledge and 3) How do we make the resulting information most accessible for the necessary policy, management, science and public uses?

Research issues vital to the prevention and control of NIS have been divided into six major areas:
1). Identification, prevention and early detection of NIS
2). Monitoring NIS
3). Research on invasion biology and impacts
4). Research on control of INS
5). Research on ecosystem restoration
6). Infrastructure for NIS research
For each of these we discuss both short and long-term priorities, and where information was available dollar amounts needed to meet these priorities. Many of the short-term priorities build off of existing programs and research, and were selected because they are important and because they represent cases where results can be achieved over the next couple of years.

Information sharing and documentation issues address the fact that our efforts related to invasive species have been hampered by the fragmented state of information systems addressing invasive species. A major challenge identified was to develop standards and protocols s that the shared core information (species names, locations, collections, effective practices, experts, etc) needed for synthetic national assessments can be reported in a cost-effective and transparent way, while still maintaining local control and responsibility for the fundamental data.

Information/documentation issues vital to the prevention and control of NIS have been divided into five major areas:
1). Inventory and assessment of invasive species information resources
2). National invasive species information system
3.) Information guidelines and standards
4). Invasive species information research and development
5). Integrating invasive species information
Implementation of the recommendations made in the above areas would lead to the development of a national NIS information system that would support all of the aspects of the National Management Plan, ranging from research and monitoring to communication and outreach.

RESEARCH AND MONITORING ISSUES

Research and technology development (hereafter indicated as research) are fundamental to the success of a national campaign to prevent, monitor, detect, and eradicate or control invasive species and to restore impacted ecosystem structure and function. R&D is necessary to address

potential, newly introduced and long established Non-native Invasive Species (NIS) that present significant potential or realized threats to the environment, economies and/or human health.

The following are some general considerations for NIS research and monitoring:

- Research will provide knowledge for assessing the risk of NIS and for setting science-based management priorities.
- Research can contribute knowledge and tools to support environmentally-sound, cost-effective and sustainable NIS prevention and management, and restoration of impacted ecosystems.
- Research should consider species, community and ecosystem level interactions.
- Research should often be place-based in order to focus on the specifics of local and regional invasions (e.g., the ecological conditions and likely pathways in an area); to place NIS research within the context of regional- and landscape-level monitoring, planning and management framework; and to define issues, evaluate risks and support recommendations.
- Long and short-term research and monitoring needs to be implemented to address the various time frames of invasions and the need for timely management actions.
- Research can benefit greatly from international activities, by tapping into international research capacity and expertise, by conducting research on NIS in their native (non-US) habitats and elsewhere where they have invaded, and by coordinating research efforts with those of our international partners.
- Research efforts should address the needs of a wide range of stakeholders, including those that may be heavily impacted by control efforts (e.g. sections of the transportation industry, of the ornamental horticulture trade, aquaculture and mariculture interests, and of the pet trade).
- Research should be linked with and provide feedback to other NIS activities.

Research issues vital to the prevention and control of NIS have been divided into six major areas:

Issue 1: Identification, Prevention and Early Detection of NIS

Research that focuses on the identification and disruption of pathways or vectors of introduction can lead to a reduction in NIS introductions. Because NIS are translocated from elsewhere, they are often more difficult to identify than native species. Systematic research and taxonomic tools are needed to enable accurate identification of NIS, which is key to linking to and using worldwide information about NIS biology and control. Once NIS are identified, systematics provides information about evolutionary relationships for predicting invasiveness of related but less studied species, a basis for determining probable areas of origin and means of spread, and guidance about potential biological control agents.

Prevention and early detection are enabled by knowledge about NIS pathways of introduction, succession patterns, socioeconomic factors related to trade, and ecology of NIS and factors influencing the vulnerability of ecosystems to invasions. Eradication of incipient NIS requires

early detection. We need to capture data on NIS from existing monitoring and sampling programs and develop new monitoring programs that can provide the early detection of NIS. As the transport of NIS continues to increase, the need for more effective and efficient detection methods is also increasing dramatically. Research on a wide range of detection methodologies will allow the timely interception of NIS in either their country or region of origin, or at their source of entry.

Suggested Actions:

- Develop a mechanism for forwarding information on known or suspected NIS to an "Invasive Species Notification System" (should be linked with "Information/Documentation" subsection of the document) in a timely manner.
- Strengthen the national capacity for research in taxonomy and systematics of NIS and integrate resources of museums and other collections into research and monitoring. This effort needs to include support for the collection and long-term maintenance of voucher specimens.
- Develop and refine the user-friendly information e.g. software, hardware, and infrastructure (including the Internet) that effectively transfer the taxonomic and systematic results for use in "flagging" potentially new invasive species and as an aid in taxonomic identification.
- Conduct pathway analysis to identify which pathways are the most likely to be major routes of invasions and incorporate this knowledge proactively into NIS prevention campaigns.
    - Characterize what factors (e.g., ecology, demography, genetics, physiology, dispersal biology) enable species to take advantage of different pathways.
    - Conduct research to identify effective measures to disrupt major pathways, intentional or unintentional, of NIS, including social, economic and political research.
- Develop survey strategies to support rapid detection in a variety of urban and rural landscapes and the interface between them.
    - Further develop remote sensing technologies and techniques to detect incipient populations on large tracts of public land.
- Develop rapid methods to screen a wide range of imports (e.g. foods, lumber and lumber products, live plants and animals, and other commercial products) for NIS at their point of entrance and at ports in their country of origin.
    - Detection technologies are needed for animals (e.g., insects), weeds, and disease organisms. These techniques should include genetic probes to allow the rapid detection and identification of NIS in both terrestrial and aquatic systems, sensory technology (acoustical, x-ray) for detection, as well as species-specific attractants (such as UV light or pheromones for insects), traps and detection survey protocols.

Priorities – Assessing Identification Capacity and Tackling Urgent Taxa

Identification capabilities and systematics research are the basis for the prevention and control of invasive species, the stated goals of the Invasive Species Management Plan. We need to know what species are present here and in other countries in order to know which to keep out of the U.S. and we need to know how to accurately identify NIS in order to make appropriate decisions.

Short-term project- Assessing Identification Capacity:

- review of existing taxonomic expertise and services in the USA and internationally and identify present gaps and potential future gaps in human capacity and infrastructure due to planned retirements or program phase-outs
- identification of a range of taxonomic groups with high invasive potential that are in urgent need of systematics research and prioritize those groups
- setting of voucher specimen and other documentation standards
- determination of currently available sources of support.

Timeline: One year

Resource requirements: $250,000

Expected Outcomes: A "business plan" of the needs, the resources (people, collections, tools, funding) available, the gaps in the research, the standards to be used, good and bad features in the distribution of resources (e.g., structure of identification services) and priorities for filling gaps. This would need to take into account national and international issues.

Lead agencies: Smithsonian and/or USDA.

Other partners and/or resources: The work should include key federal agencies providing taxonomic services (e.g., Smithsonian, USDA, USGS, NOAA, DOD, NSF), representation of the broader national provider community (e.g., academic institutions, Association of Systematics Collections), and key stakeholders using and/or providing taxonomic services and information. Partial models of this kind of plan have been carried out by Bionet International, Australian Biological Resources Study and LandCare New Zealand. The plan should also accomodate any parallel studies that undertaken by the Global Taxonomy Initiative and by GISP.

Long-term project - Tackling Urgent Taxa: Undertake a thorough, worldwide taxonomic treatment of 3-4 taxonomic groups of organisms known to contain invasive species but for which we cannot differentiate good from bad. Such a long-term plan should be implemented immediately because:

- we can identify a few groups immediately that are universally recognized as understudied and posing a high risk as invasives of agricultural and natural resources,
- we have the scientific expertise within federal agencies to study these groups but they lack the funding to do so,
- these projects would serve as models for future such programs identified during the short-term project,
- we already have a base of collections of these organisms with their associated information which is essential for use in risk assessments and decision-making on invasive species but is not presently easily and widely available (i.e. not computerized).

The groups to be studied should be determined by a committee of USDA, DOI, DOC, and Smithsonian representatives. Examples that should be considered include snail-associated strongylid nematodes that can cause animal and human diseases, slugs, including serious plant

pests, which might transmit human and animal diseases, lesion nematodes, obligate fungal plant parasites, (e.g., recently introduced powdery mildews plaguing the ornamentals industry), and selected arthropods (including thrips, white flies, leafmining flies, moths and mites) associated with tremendous increases in export of vegetables, fruits and flowers from tropical countries.

Timeline: Five years.

Resource requirements: $5 M per taxa

Expected Outcomes: For each taxa a professionally produced user-friendly identification tool, which should increase the efficacy of identification, interception and prevention.

Lead agencies: USDA.

Other partners and/or resources: For each group the work should include a team new and existing personnel (e.g. a team of 15-20 scientists, post-doctoral researchers and graduate students) in multiple places, including federal labs, academic institutions and at partnering international institutions.

Priority – Prevention Infrastructure for New NIS

Suggested Actions: Develop sampling techniques and strategies, as well as the associated infrastructure, to detect, report, and map the presence of "new" NIS. These strategies are likely to include both qualitative surveys by experts and incidental reporting by the public and stakeholders (e.g., power plant operators, farmers). Involvement of the public and stakeholders will require both training and organizations to report the "new" species. A special need is the development of the techniques and infrastructure for emergency responses to map recently released noxious pests (e.g., Asian longhorn beetle). A rapid response is critical to control recently released pests while they still have a limited distribution. A rapid response (e.g., "Swat team") will require coordination among federal, state, and local agencies, the ability to rapidly allocate resources to the appropriate organization(s), and sampling and control techniques appropriate to the pest and the spatial scale (e.g., use of a stronger pesticide to eliminate a pest from a limited area that would not be acceptable on a large scale due to cost and/or environmental concerns).

Expected Outcomes:

1) Qualitative survey designs and protocols to determine presence/absence of invasive species in key aquatic and terrestrial habitats.

2) Infrastructure to support regional and/or national points of contacts for both scientists and the public to report occurrences of "unusual" species. The points of contact are likely to consist of a tiered systems of "para-taxonomists" (e.g., field ecologists, contractors), existing organizations (e.g., extension agents, museums), and recognized world experts in taxonomic groups.

3) Regionally-specific training materials (e.g., brochures, videos, public announcements) for the public and stakeholders to alert them of potential invasive species and points of contacts.

4) Development of "emergency response plans" by invasive species type (e.g., insects, weeds, plant diseases, aquatic nuisance species). These plans would serve as templates for the implementation of a rapid response for each invasive species type, modified as needed for the specific pest and location. The plans would include general monitoring approaches, roles and responsibilities for each federal, state, and local agency, and list points of contact. The plans would also include recommendations as to appropriate control technologies, including costs and environmental risks, for different types of pests at different spatial scales.

Timeline:

1) Qualitative survey protocols for key habitats and pests - 2002
2) Development of regional & national points of contacts - 2003 and on
3) Regionally-specific training material - 2001 and on
4) Emergency response plans by type of habitat and/or pest - 2002 and on

Lead Agencies: USDA, DOI, DOC, EPA, others

Resource Requirements:

1) Qualitative survey protocols - 350K (assuming at least 50K per habitat or pest for a paper excercise)
2) Regional & national points of contact - 1M (this is very tough and the Info. people might have a better estimate)
3) Regionally-specific training materials - 500K (again this is tough as it depends upon the number of regions, etc.)
4) Emergency response plans - 600K (a rough estimate, most of cost to contractor for a paper excercise and to coordinate among states, etc. Needs to be done for each pest type)

Issue 2: Monitoring for NIS

As used in this document, monitoring refers to EITHER SYSTEMATIC SAMPLING FOR OTHER PURPOSES (WHERE NIS ARE COLLECTED INCIDENTALLY) OR TO PROGRAMS WHICH quantify the distribution and abundance of NIS in the field. Early detection OF NIS at the points of entry AND their taxonomy are addressed in other sections.

The distribution and spread of NIS are often unknown for many species. Monitoring data that are available for a given species are often based on a variety of approaches, with different sampling efficiencies. Other monitoring is occurring in which NIS are being collected incidentally. A comprehensive survey of these efforts is needed.

Some agencies (e.g. NOAA, EPA, APHIS, FS, FAS, States) are already involved in monitoring for the introduction and spread of NIS, but coordination among these monitoring groups is needed. International cooperation and coordination is also needed in a comprehensive monitoring program.

Monitoring should be done for targeted NIS, as well as, for species that cannot be predicted to be invasive.

Our ability to monitor some NIS is limited because the present sampling techniques require labor-intensive methods. More effective and efficient monitoring techniques are needed. The specific methods and sampling strategies will vary both between the type of invaded habitat (e.g., terrestrial vs. aquatic) and the stage of the invasion.

The general public can become an excellent source of monitoring information regarding new introductions and spread of NIS. Mechanisms for training, informing and incorporating the public's input are needed to aid in the tracking of NIS

Suggested Actions:

- Develop a comprehensive inventory of current environmental monitoring programs, systems and techniques including those specifically for NIS, and evaluate each for its potential to cost effectively contribute to a national or regional monitoring program.
- Develop scientifically sound, cost-effective approaches to quantifying the distribution and abundance of terrestrial and aquatic non-indigenous species at various stages of invasion and at different spatial scales. Apply these approaches to both presently invaded and vulnerable ecosystems. The primary goal of the monitoring research is to develop the methods and data needed by resource managers and planners in NIS decision making.
- Develop sampling techniques to sample invasive species with known and acceptable levels of uncertainty. These should include:
    - development of standardized techniques where possible, with intercomparability studies where standardization is not feasible;
    - development/validatation remote sensing technology to monitor both terrestrial and wetland habitats, including hyperspectral analysis to distinguish plant species and their "health".
    - development/validatation of genetic fingerprinting techniques as a method to identify microbes in various media and as a cost-effective method to monitor for the presence of invasive phytoplankton and/or the larval phases of invasive animals (e.g. green crabs) in water columns.
    - development of monitoring designs for various stages of invasions for different habitat types.
    - development of strategies, and the associated infrastructure, to detect and report the presence of "new" nonindigenous species. These strategies are likely to include both qualitative surveys by experts and reporting by the public and stakeholders (e.g., power plant operators). Involvement of the public and stakeholders will require both training and organization to report the "new" species. (NEED SOME CLARIFCATION ON THIS LAST SENTENCE)
    - development of strategies for regional scale evaluations. Research could include determining the optimal sampling strategy at different scales and an evaluation of the statistical uncertainties and costs associated with probability-based sampling versus fixed site sampling.
- Conduct place-based monitoring studies in different habitats and at different spatial scales. The purposes of these pilots include: 1) determining the extent and nature of

invasion in high priority sites/regions and 2) evaluate various sampling designs and techniques.

  - Intensively monitor a suite of fixed sites (e.g., parks, research sites, including aquatic and terrestrial systems) in a range of habitat types on a periodic basis to evaluate the occurrence of new invaders, the spread and life history of established NIS, and impacts on ecosystem structure and function.
  - Conduct regional-scale studies to evaluate the extent and nature of invasions. The spatial scale should be sufficient to be ecologically relevant to the invasive species and sufficient to design management plans.
  - Develop hierarchical approaches so that data at each spatial scale and/or stage of invasion feeds into the next scale. One goal is to develop a tiered monitoring approach.

- Develop the infrastructure to enhance coordination among state, federal, tribal, university, and international organizations. This requires integration across geographic regions, taxa, and habitat types. The goals are to 1) reduce redundancy in data collection, 2) rapidly identify new invaders and/or the spread of established invaders, and 3) allow the integration of data collected at different spatial scales.
  - Develop an easily accessible invasive species monitoring data acquisition system (ISAS) that links monitoring data with research results, identification information, and ecological and control information about NIS.
  - Train resource managers in the use of monitoring protocols and mechanisms of reciprocal feedback between monitoring and management.

Priority: Increasing Monitoring Knowledge and Capacity

In the earliest stages of designing efficient NIS monitoring systems, a short-term priority to increase NIS monitoring capacity is to expand the efforts of some successful and ongoing monitoring programs.

We suggest below three examples of projects to which an enhanced NIS component could be added to yield great benefits. Although the WG did not have time to develop a comprehensive framework for establishing priorities across habitat type and/or type of invasive, these projects in combination nonetheless address fundamental monitoring research needs, include both terrestrial and aquatic on both coasts and in mid-America, are large regional studies, evaluate and develop new monitoring techniques/approaches, are high priority studies within their agencies, and include both short-term and long-term outputs. In addition, by building onto ongoing projects, they take advantage of existing infrastructure and also enable the simultaneous collection of data that might elucidate interactions among different environmental stressors.

Example 1: Western EMAP, a survey of the non-indigenous benthos and fishes of the coastal ecosystems of the West Coast.

Western EMAP is deriving regional estimates of the ecological condition of the coastal ecosystems in California, Oregon, Washington, Hawaii, and Alaska. Invasion by non-indigenous species is one of several factors currently being evaluated. By using comparable techniques, standardized taxonomy, and probability-based sampling design, EMAP will generate statistically unbiased estimates of the extent and nature of invasions along the entire West coast.

To capitalize on the planned short-term EMAP outputs, we propose new, long-term research that would include developing regional guides to non-indigenous species, evaluating the vulnerability of different ecosystems/regions by determining the relationship between invasions and anthropogenic stressors (e.g., contamination, ballast water discharge) and ecosystem characteristics, and coupling the regional assessments with intensive surveys and mechanistic studies at fixed sites identified through the regional surveys.

Expected outcomes of NIS enhancements:

- Taxonomic guides to the non-indigenous benthos and fish and their natural history by biogeographic regions of the West Coast.
- Evaluation of the relationship between the extent and nature of invasions and anthropogenic stressors and natural characteristics
- Intensive surveys and mechanistic studies on impacts of non-indigenous species at fixed sites identified as either highly invaded and/or vulnerable from the regional surveys

Lead agency: U.S. EPA (in partnership with NOAA and WA, OR, CA, AK, and HI).

Resources required: TOTAL FY 02-04: $2.05 M
Note: These funds leverage the approximately $15M already committed to Western EMAP from other sources for FY02-04.

Example 2: Delaware Basin Invasive Species Monitoring example

Several agencies (USDA, DOD, EPA, DOI, States and others) and New York City are pilot-testing the integration of their monitoring programs in the Delaware Basin. Developing monitoring systems for invasive plants, insects, and pathogens integrated with forest health and water quality monitoring is one of the goals of this pilot. The pilot test involves the forested upper Delaware River basin which is the New York City water supply, the agricultural dominated mid basin, the Delaware estuary, and the wildland urban interface and urban areas of the lower Delaware basin and New York City. The pilot study is being used to develop methods to link the various levels of hierarchical monitoring which is occurring in the Delaware Basin.

The NIS monitoring capacity of this project could be greatly enhanced by the following additional activities:

- For remote sensing monitoring, developing methods for ground truthing remote sensing based models of vegetation habitat types for NIS risk analysis and for identifying habitats at risk of NIS invasion.
- For grid-based survey systems, developing an urban/wildland interface NIS indicator and testing of it around ports and developing efficient field monitoring methods for Asian Longhorned Beetle (ALB).
- For intensive site ecosystem monitoring, developing indicators for NIS not visible during the annual summer visit to the grid sites or by remote sensing, and conducting detailed studies on NIS to identify biological thresholds to interpret grid and remote sensing data.

Expected outcomes of NIS enhancements:

Enhanced understanding of NIS in the context of many changes ongoing in the Delaware Basin
Development of monitoring techniques applicable elsewhere (e.g., remote sensing, ALB, urban/wildland interface)
Extensive data on NIS that occur in multiple habitats (e.g., agricultural land, forests and urban lands)
Extensive data from several approaches for many invasives in many habitats, enabling analyses of most effective methods

Timeline: Some of the activities (e.g., remote sensing, ALB monitoring) could be accomplished in 2-3 years, while others (e.g., urban/wildland interface monitoring) would take over 5+ years.

Lead agency: USDA, EPA and others

Resources required: Approximately $5M/yr
Note: These funds leverage the fund (10's of millions/yr) already committed to this activity from other sources.

Example 3: Long Term Resource Monitoring Program in Upper Mississippi states

The Long Term Resource Monitoring Program (LTRMP) is a project that involves five upper Mississippi River states (Minnesota, Wisconsin, Iowa, Illinois and Missouri). It includes systematic sampling of fish, invertebrates, vegetation communities and water quality at fixed sites on the Upper Mississippi River and at one site on the Illinois River. This project has been funded by the Army Corp of Engineers through the USGS. The LTRMP is the largest river monitoring program in the country and has been ongoing since 1989.

For a relatively small amount of funding, it is possible to add a strong invasive species focus to this project. Part of this enhancement could expand the LTRMP monitoring program in the Illinois River to include the Illinois Waterway System in Chicago, a system of interconnecting channels and natural rivers that directly links the Great Lakes and the Mississippi River basins. Already the zebra mussel has been spread the length of the Mississippi River, and new recruits to the Illinois and Mississippi river populations come from Lake Michigan each year. The round goby has just begun to invade the Illinois River from Lake Michigan and the African zooplankter, *Daphnia lumholtzi*, has been moving up the Illinois River and is now on the verge of entering the Great Lakes.

Expected outcomes of NIS enhancement:
Invasive species data collected over the last 10 years would be analyzed and reported.
The present monitoring program would be expanded both in time and space, and with modified gear, to specifically learn more about the abundance, distribution, and life histories of invasive species.
A report would be produced that would provide specific information on invasive species (particularly grass carp, bighead carp, silver carp, white perch, round goby, zebra mussels - adults and veligers, and the zooplankter Daphnia lumholtzi). The status of each species would be described.

Addition of the Illinois Waterway System to the monitoring program would provide better understanding of the present status of specific invasive species in this system and could provide needed data to prevent or control the spread of some of species.

Required resources: $1M/yr for LTRMP, plus $500K to add Illinois River. Note: These funds would leverage the approximately $18M already committed to this project.

Timeline: 1-2 years to analyze past data, and to gear up for extensive monitoring; longer-term to protect these two basins that drain portions of 30 states and two Canadian provinces.

Lead Agency: USGS

Issue 3: Research on Invasion Biology and Impacts

For many organisms we know little about their ability to invade new habitats, the factors that enable them to invade, the kinds of habitat or habitat change that enhances invasion, and spatial, temporal and systems details on the process of an invasion. Likewise, the impacts of NIS are not well understood at many levels including as individual organisms, members of communities and ecosystems, or at the level of the human system which the NIS invades. Better methods are needed to analyze and model NIS dynamics and impacts. This information would help identify potential NIS and their pathways of introduction, and provide essential management decision support once an NIS has been introduced or established.

Suggested Actions - Invasion Biology:

- What factors (e.g., ecology, demography, genetics, physiology, dispersal biology) make species invasive and what are the most susceptible life stages of NIS for control actions?
- What causes the lag period often observed between incipient populations and outbreak conditions.
- What biological properties (e.g., community structure, biodiversity) and what kinds of human impact (e.g., urbanization, environmental stress such as climate change) make communities and ecosystems vulnerable to invasions?
- What are the dynamics of invasions, especially during the lag phase, and are epidemiological approaches useful in understanding these dynamics?
- What are the human dimensions of invasion biology (e.g., how do humans act as vectors, and as selective agents)?
- What changes occur during invasions (e.g., rapid evolution, hybridization, plasticity) in invading species and in the community/ecosystem of species being invaded?
- How do NIS serve as vectors for plant, animal and human disease, for microbial communities, and for other NIS?
- How does ecosystem structure and function relate to NIS invasion or spread?

Suggested Actions – Invasion Impact:

- How NIS influence how populations of native species respond to cumulative stresses. Methods and models need to be developed and validated.

- How NIS can lead to habitat alteration and loss of native biodiversity, including native genetic diversity. Research focus is immediately needed on NIS effects, including effects of introduced disease organisms, on habitats and on populations of species of concern (threatened and endangered species, rare plant and animal assemblages).
- How NIS can alter water chemistry, nutrient cycling and/or disturbance regimes**,** e.g., where a NIS fixes nitrogen and so enhances additional invasions, where NIS alters nutrient cycling so as to increase fire frequency, or where NIS influences pollutant fate and effect.
- How NIS can influence soil moisture and water resources, e.g., how aquatic plants alter soil moisture and ground water level, choke out water-borne transportation, reduce water storage capacity, and alter recreational activities.
- How NIS influence soil erosion and microbial ecology via their influence on surface water runoff and sediment yield, soil moisture and soil texture, and abundance of beneficial soil symbionts, such as mycorrhizal fungi.
- How NIS can influence secondary and higher-order effects on ecosystem goods and services, e.g., via effects on pollinator services, or on trophic interactions that alter populations of fish, waterfowl and large mammals of ecological and economic importance.
- How NIS EFFECT grazing and agriculture, because many exotic plant species are noxious to native wildlife and livestock, and NIS can become serious pests in croplands.
- How impacts of NIS change under different habitat and management conditions. Both short-term and longer-term cumulative effects should be considered. This includes how NIS impacts provide opportunity for other NIS to become established.
- How NIS can potentially and/or actually impact human health, including both direct effects (e.g., NIS are exotic diseases or vectors for disease) and indirect effects (e.g., increased exposure to pesticides used to control NIS).
- How NIS have economic impacts, including direct losses due to loss of natural resources or loss of ecosystem services, costs of combating NIS and/or cost of providing incentives to change behavior/lessen threats, and potential economic benefits of NIS. Develop information needed to compare economic advantages of treatment and prevention alternatives.
- Improve modeling capacity to better assess interactions of NIS and their long-term cumulative impacts (e.g., modeling of interactions between NIS and native species at a landscape scale) in order to aid both risk assessment and mitigation strategy.
    - Such models should include spatially-explicit population models for key native species to predict NIS impact on population sustainability and distribution. Advanced modeling research is also needed to enable the coupling of climate models with NIS models because changes in soil moisture, growing season length and atmospheric carbon can favor many NIS.
- Develop and validate a suite of indices of ecological structure or "health" that incorporate NIS. To the extent possible, these indices should be linked to specific ecosystem services or goods so as to allow better communication of the impacts to the public and decision makers.

Priority – Develop a Framework for Invasiveness

Suggested Actions: Develop a framework for identifying the scientific basis of invasiveness by standardizing data collection that will allow for 1) development of analytical methods and modeling of NIS dynamics and 2) comparison between species for factors that can be used to predict invasiveness of other organisms. This information will help identify potential NIS, their pathways of introduction, and provide essential management decision support once an NIS has been introduced or established.

Expected Outcome: A standardized data collection framework for invasive species research.

Timeline: Short term (<2 years) as the National Research Council (NRC) has been commissioned by USDA APHIS PPQ to coordinate a committee to determine how to study and predict invasiveness, i.e. the scientific basis of invasiveness and research areas from which information is needed to predict invasiveness.

Lead Agencies: Federal and state agencies, university and private research institutions, and non-governmental organizations should be involved in this process. The effort initiated by APHIS PPQ must also be expanded to include species other than plant pests.

Resource Requirements: Initial funding has been provided by USDA APHIS PPQ. Additional funds will likely be needed to expand the scope of the NRC committee to include non-plant pests. An estimate of $200,000 over a two year period to cover travel expenses and administrative costs.

Priority - Place-based Studies

Suggested Actions: Conduct place-based studies to compare biological and ecological factors (as identified in action above) that enable a species to invade.

- Identify representative species of taxa which are at high risk of introduction or recently introduced into the United States, e.g., noxious weed, insect pest, disease microbe. It may be necessary for comparative studies to be conducted for multiple species within a specific taxon to evaluate the applicability of predictive models across species. The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), is an ideal candidate for this study because of its distribution; frequency of introduction into a range of habitats; the wealth of biological, genetic, and ecological data available; and the extensive international collaborative research efforts currently being conducted.
- Conduct comparative study in site of origin, sites of introductions in other countries, and in the US. This study will allow to evaluation of factors involved in invasion of new ecosystems.
- Monitor ecosystem for impact of NIS.
- Monitor the NIS for genetic and physiological changes upon introduction and for evolutionary changes by comparison of populations that have invaded at various times.

Expected Outcome: Predictive models for invasiveness based on clearly delineated biological and ecological factors.

Timeline: 3-7 years are required to coordinate, conduct, and evaluate these studies. The minimum time would be realized if species were chosen that are already under extensive study, e.g., the Mediterranean fruit fly, Pink Hibiscus Mealybug, Silverleaf whitefly.

Lead Agencies: Involvement of collaborators in foreign countries is essential and may be developed through the USDA Foreign Agricultural Service and the Food and Agriculture Organization of the United Nations. These studies must be a collaborative effort of university, state, private research institutions, non-governmental organizations, and federal agencies.

Resource Requirements: This effort will require a coordinated funding effort by multiple US granting agencies, e.g., CSREES and NSF, participation by international groups whenever possible, e.g., BARD. There must be a mechanism for funding of collaborators in foreign countries in order to insure their participation. The cost of these studies will depend upon the species chosen. It should be possible to conduct this work in conjunction with ongoing projects to maximize the funds invested. A conservative estimate for each study of each taxon is $1 million per year for a 3 year period.

Issue 4: Research on Control of NIS

Research on developing timely as well as effective control methods is needed to address NIS problems. Research should focus on what will be needed in the future, in addition to addressing the current problems. Long-term environmentally sound control methods are required for any major invasive species infestation, but many times short-term goals drive the control research programs. Quick and rapid treatment of a problem may lead to significant long-term environmental impacts.

Research to control NIS, especially research on biologically-based options, will often require the collaboration of international partners in order to find appropriate control measures that have worked elsewhere INCLUDING biological control agents that control NIS IN THEIR NATIVE HABITATS.

Research on short-term controls often interest private contractors that engage in multiple applications and repeat business. Research on long-term controls is usually provided by government agencies (federal and state) and non-profit organizations where there is little immediate return on research investment, but long-term prospects of lower total control costs and sustainable control using bio-based technologies.

Research needs to be directed at providing a range of control outcomes (e.g., SLOWING THE SPREAD TO complete elimination of the NIS, return of habitat to utilization), time frames (from rapid removal to reclaiming habitat for the future), and targets (from a specific NIS to a habitat or group of NIS).

Suggested Actions: Enhance current research activity to address the following topics:

- Evaluate previous NIS control actions (both successful and unsuccessful) as case studies to help guide future control campaigns.

- The development of integrated control tactics (e.g., host-plant resistance, biological control, GMO technologies, habitat management, ballast water management, and/or chemical, physical and mechanical tools). Conduct socio-economic research to determine acceptance levels for different types of control measures, and tolerance of impacts.
- Research to develop comparative risk assessment methods to quantify both the ecological and human health risks from control measures (e.g., pesticides) versus the spread and future risks associated with establishment and spread of NIS.

Priority – Enhancing Environmentally-Sound Intervention Technologies

THERE IS an immediate NEED FOR significantLY increaseD levelS of integrated research to HELP THOSE WHO MUST coordinate and deploy NIS control tactics across the wide range of ecosystems and socio-economic conditions they impact. There exists a substantial knowledge base ON NIS CONTROL AND THE methodology to resolve many NIS problems has been developed in various federal and state agencies, universities, and private institutions. However, lack of coordination among the various working parties, and inadequate and inconsistent funding hinders sustained management of many NIS. There is also inadequate information regarding THE biology of many NIS in their NATIVE HABITATS. The establishment of international cooperation and foreign exploration in the home range of the NIS is critical to the identification, characterization and control of NIS, to the development of integrated strategic research and to the implementation of action plans to lessen or eliminate their impact on ecosystems in the United States.

Suggested Action One: Increase the level of research on biological control - Biological control can be the foundation of ecologically sustainable NIS intervention. While the problems and methodologies of biocontrol are known for many NIS, inadequate personnel, limited quarantine and rearing facilities, and in some cases, inadequate information on the ecology of the NIS in its home range, hinder effective NIS management. Increased funding is needed to resolve staffing inadequacies and allow for the construction of new or upgrading of current containment/research facilities. Increased international collaboration is required to allow strategic research to be conducted in the home range of the NIS which may be directly applied to the problem in the United States.

Suggested Action Two: Increase the level of research to reduce the vulnerability of species, communities and ecosystems by fostering novel habitat management strategies including host plant resistance. The environment may be managed to reduce the vulnerability of species, communities, and ecosystems to new and established NIS and to enhance resilience to invasions. Inherent in this approach is an inventory and characterization of the most vulnerable components of the system, and the deployment management strategies emphasizing germplasm conservation and development (host plant resistance), characterization and conservation of critical habitats of natural enemies, and establishment of stabilizing feedback systems at the community, landscape and ecosystem levels. As some systems have been irreparably altered by NIS, research is needed to replace extinct or irreparably damaged components of the system with those better adapted to current biotic conditions.

Expected Outcomes and Timeline:

- Increase in the amount of domestic and international collaboration on specific NIS problems. Should be observable increases within 2 years.
- Increased number of research facilities (PARTICULARLY QUARANTINE AND REARING FACILITIES) suitable for research on NIS-related organisms. Observable increases within 5 years.
- Increase in the number of NIS controlled, reduction in the area affected by NIS, reduction in the rate of spread of various NIS. Observable changes due to research implementation 3-10 years. While we anticipate some rapid and striking successes due to biocontrol activities, most observable impact will likely occur after a latency period where introduced and indigenous natural enemies establish and begin to exert significant mortality on NIS.
- Reduction in the amount of pesticides employed against NIS. Will occur concurrently with successful establishment/rehabilitation of natural enemy systems and habitats.
- Reduction in crop losses due to NIS. Increase in area of habitats returning to pre-NIS status.

Lead Agencies: USDA, DOI, DOC,

Resources Requirements: An increase of $25 million per annum deployed across multiple agencies for at least 5 years.

Priority - Aquatic Ecosystems: Ballast Water Exchange and Treatment Alternatives

Ballast water exchange and treatment alternatives are major NIS control issues in both freshwater (e.g., Great Lakes) and coastal systems.
Suggested Actions: Develop and validate methods to treat ballast water sufficient to remove target organisms ranging from human viruses to dinoflagellate cysts (<20 microns) to fish and invertebrate larvae. Methods need to be validated for removal efficiency, cost-effectiveness, ship safety, and practicality under "real world" conditions. Potential ballast water treatments include, but are not limited to, 1) filtration and centrifugation; 2) biocides; 3) UV; 4) heat; 5) shoreside or onboard treatment systems; and 6) providing clean ballast water (e.g., freshwater). Any proposed approach needs to be tested using standardized methodologies for effectiveness.

Expected Outcomes:
- Standardized methods and protocols to evaluate efficiency of ballast water treatment techniques.
- Develop and conduct “bench-top” testing of ballast water treatment technologies.
- Ship-board and/or shoreside tests of promising ballast water treatment technologies suitable for the defined target organism(s).

Timeline:
- Standardized methods and protocols by 2002.
- “Bench-top” methods by 2003.
- Ship-board and/or shoreside evaluations of promising technologies by 2004 and 2005.

Lead Agency: NOAA, Coast Guard

Resources Requirements: 1) "Bench-top" development and evaluation: 1.5M, 2) Field (ship or shore-side) tests of select treatments: 2.5M, 3) Development of standardized method to test treatments: 300K

Issue 5: Research on Ecosystem Restoration

Research on ecosystem restoration is needed to direct the formulation of NIS control objectives, and to aid natural resource managers with restoration decisions once targeted NIS have been removed or controlled. Restoration is likely to become a larger issue for land management agencies, and become a particular concern where NIS come into contact with species protected by the Endangered Species Act.

Suggested Actions: Conduct research on restoration biology to develop the best methods for reintroducing or promoting locally adapted native species into the native habitat after NIS control measures have been applied.

Recommendation: Germplasm-related research should be administered through the National Genetic Resources Program (USDA-ARS) in conjunction with the National Seed Storage Laboratory (NSSL) in Fort Collins, CO. The National Genetic Resources Program (NGRP) is responsible for the acquisition, characterization, preservation, documentation, and distribution to scientists OF germplasm of all organisms important for food and agricultural production. The NSSL has traditionally stored seeds of crop plants and their wild relatives, but now is storing animal semen. For nonagricultural plants and animals, there is presently no agency or program with overall responsibility. We suggest that the NGRP's scope be broadened to include A GREATLY EXPANDED LIST OF plants and animals, and that funding for all germplasm research and collection be administered by NGRP. Within NGRP, there already exists committees of scientists, including the Crop Germplasm Advisory Committees, that review proposals to fund collection trips. We propose that a committee of scientists be formed in a similar framework to review NIS-related germplasm research proposals and collection activities.

- Conduct research on germplasm sampling, preservation protocols, and conservation strategies on species or communities threatened with extinction or significant gene pool depletion by NIS.
- Develop and disseminate science-based technical information to guide the restoration of affected ecosystems. Technical assistance can be based on existing scientific information if available, but in many cases there is a need for demonstration projects, an assessment of historical treatment practices, or other approaches to developing information and advice for land managers.

The majority of research related to germplasm issues has been conducted on higher plants and animals, usually in conjunction with agriculture. Virtually nothing is known about preserving germplasm of lower plants and animals, e.g., liverworts or slugs, and organisms that are not commercially utilized. A similar case can be made for wetland species.

Animal Example: While we tend to think of vegetation as providing the primary habitat for other organisms, sometimes it is animals that form unique communities. Examples include coral reefs, oyster bars, and in fresh water mussel beds. In many large rivers, unionid mussels are being threatened by the exotic zebra mussel. This is particularly true in the Illinois and Mississippi rivers. Some research has already been conducted and more needs to be carried out to evaluate the use of artificial ponds and "clean" river areas as temporary holding locations for mussels until the immediate threat of zebra mussels has passed or until artificial propagation has been successfully developed. In some areas such as the Illinois River, upstream sources of zebra mussel larvae may have to be eliminated so that once productive mussel beds can be restored. This is an excellent example where research on various mussel species biology and life history will have to be integrated with various management strategies where mussel populations need to be protected or restored.

Plant Example One: Mature American chestnut populations have been devastated by two exotic fungal diseases, *Phytophthora cinnamomi* (ink disease) and *Cryphonectria parasitica* (chestnut blight). Currently the species exists only as stump sprouts that are usually killed by blight about the time of sexual maturity. Old range maps indicate that American chestnut occurred in a much wider range than the present distribution of sprouts. Verified reports of sprouts in Tennessee show a dwindling population in middle Tennessee and no sprouts in western Tennessee, where chestnut was common. Using conventional seed storage methods, chestnut seed cannot be stored over single year and successful grafting of sprouts is difficult. Research on vegetative propagation of shoots/buds from sprouts may provide a solution to rescuing populations that are in danger of extinction. Alternately, studies on cyropreservation of seeds, excised embryos, and organogenic and/or embryogenic tissue cultures could be another avenue of research toward perserving gene pools from different populations.

- Research on the compatibility of NIS control strategies with restoration objectives

Plant Example Two: The Midewin National Tallgrass Prairie near Joliet, Illinois is an important example of a place where this kind of research needs to be conducted. Midewin is located on the old Joliet Army Arsenal, and is a 19,000 acre site that IS beING co-managed by the U.S. Forest Service and the Illinois Department of Natural Resources. This IS the largest tallgrass prairie restoration effort in the country. The restoration is complicated because the site is highly disturbed in places and because of the presence of many exotic plant species such as autumn olive, garlic mustard and reed canary grass. While fire is one of the tools that will be utilized in restoration efforts, it is unclear if fire alone will control autumn olive or garlic mustard. Research IS needed to determine control strategies for exotic plants at Midewin that will allow restoration efforts to proceed, and that will be compatible with the long-term management plan for Midewin. Because this is an ongoing restoration effort, a relatively small infusion of new funds FOR RESEARCH AND MONITORING (around $200K per year) would greatly assist in addressing the issue of invasive plants and their effects on restoration. Results of these studies could also be very valuable as a guide to other similar restoration projects.

- Research on the methodology of restoration of host species and communities

Plant Example Three: Eastern hemlock populations have been impacted by hemlock woolly adelgid, a NIS from Asia. Hemlocks generally occur in riparian zones along streams and rivers.

There appears to be promising biological controls for the adelgid that were introduced from Japan and China. Hemlock populations in some watersheds, however, have been completely eliminated or severely damage to a point where natural regeneration is questionable. Little is known about how to successfully plant hemlock seedlings on these riparian sites, OR WHAT the impact OF planting will have on the plant and animal communities inhabiting the site and on the water quality of associated streams. Studies are needed to define site preparation requirements, planting methodology, and seedling standards to ensure successful regeneration with minimal disturbance to the ecosystem.

Wetland Example: Remediation and construction OF NEW WETLANDS is a major approach to achieve the "no net loss of wetlands" policy. However, there is increasing concern that constructed wetlands are often rapidly invaded by exotics, thereby negating the original purpose of the restoration effort and potentially creating a seed source for exotics. Therefore, a high priority research need is to develop and validate methods to construct and/or restore freshwater and coastal wetlands to minimize invasions of exotics species while maintaining key wetland functions. This would cost about $2 M per year for both freshwater and coastal wetlands.

Issue 6: Infrastructure for NIS Research

Infrastructure refers to the funding and capacity available for invasive species research and technology development, as well as organizational mechanisms that support planning and coordination. The National Science and Technology Council (NSTC), Invasive Species Task Force has documented for several years the full funding needs for agencies with invasive species R&D programs. In general, federal agencies have been funded at one quarter of their estimated need. Additionally, there is little flexibility in the available funding to initiate emergency research that is often critical to stem the spread of incipient NIS invasions. Organizational mechanisms ARE needed for research planning, coordination, and integrated project implementation and support related to cross-cutting technologies (such as monitoring, risk assessment, pathway analyses). The mechanisms would cross agencies, universities, states and others. Strengthening the dialogue between research managers, and between research managers and stakeholders, is essential if limited resources are to be used effectively.

Suggested Actions:

- Strengthen and establish new venues for R&D information sharing, planning and project level coordination for regional or national level concerns. This should include:
  - Establishment of a mechanism for informing researchers of management needs, including efficacy of control strategies, sharing information, and coordinating research. Expansion of the charter for the NSTC Invasive Species Task Force could serves to identify current and future national research program and funding needs. The NSTC invasive species task force would draw upon existing technical, interagency committees (FICMNEW, ANSTF) & two proposed committees, one on insects and one on pathogens, in the drafting of criteria for proposal requests and for input on funding recommendations.
  - Assessment of national capacity for research on NIS at university, local, state, regional, federal and international scales. Such an assessment will allow a delineation of research responsibilities and capabilities.
  - Coordination with monitoring groups, groups managing NIS information resources, and, perhaps most importantly, with groups that have responsibility for managing NIS. Such

an effort could be coordinated by a standing interagency committee with responsibility to ensure the prompt response of research to provide knowledge needed in NIS control efforts.

- Advise on the balance across the many dimensions of NIS research e.g. prevention vs. control, new vs. old NIS, U.S. vs. international perspectives, applied vs. pure research, research for predictive and rapid response purposes vs. research for descriptive, long-term purposes, and research that is interdisciplinary vs. disciplinary.

- Enhance funding needed for core federal invasive species R&D programs. This includes funding to enhance the infrastructure needed to carry out significant NIS research; e.g., to address the current shortage of containment facilities needed to conduct research on NIS and biological control. [contact Sheila Andrus for current NSTC Invasive Species Task Force budget figures].

- Establish a "flexible" research fund in the amount of $60 M per year, to be administered by DOI, Commerce and USDA. EXPEDITED CONTRACT MECHANISMS TO PROVIDE FUNDS TO NON-FEDERAL GROUPS WOULD BE NEEDED. Note that this funding amount would provide for a rapid research response for 3-4 species per year, for each of the following sectors impacted by invasive species: aquatics, agricultural systems, and natural areas. Funding would support initiation of "emergency" research critical to detection and eradication of newly introduced/discovered invasive species that pose a high threat to the environment, economy and/or human health. Flexible funds would not take the place of core, long-term research program support; rather, these funds would ensure the advantage of time on the side of control and containment. Such projects would support a rapid R&D response, including intelligence gathering in the species' country-of-origin soon after it is first detected.

- Establish a federal Multi-agency NIS Competitive Research Initiative - a new Federal Multi-agency NIS Research Initiative to draw together unique R&D expertise to focus in an integrated manner on some of the most urgent and difficult NIS problems. This program would develop incentives for enterprising, interdisciplinary research that optimizes the use of technologies outside resource disciplines most closely associated with biological invasions. For example, application or radar and sonar technology for tracking insect dispersal; application of satellite imagery for invasive plant monitoring; application of computer artificial intelligence technology for integration of models and GIS data, among others. The recent federal multi-agency competition on "The Ecology of Infectious Disease" could serve a model.

Priorities –Increase Coordination and Competitive Research Intitiative

1) Establish research steering committee linked with federal NIS coordinating groups, i.e., FICMENU, MENDS, SAFR, to set national research goals and priorities. IT IS IMPORTANT TO HAVE REGIONAL, STATE AND LOCAL REPRESENTATION ON THIS COMMITTEE TO ASSURE THAT PLACE-BASED PRIORITIES ARE BEING MET. The first tasks of THE steering committee would be to establish new sub-groups on insects and pathogens, to

commission an assessment of research capacity, and to design a mechanism for administration of flexible research fund.

Expected Outcomes:

- Better coordination and communication of research plans, budgets, and outcomes.
- Increased ability to plan coordinated activities across agencies, regions and taxa.
- Increased ability to establish national priorities for NIS research.
- Ability to determine the dimensions of the needed assessment of research capacity.
- A coordinated plan for inititiating and administering a flexible research fund for rapid response to new NIS threats.

Timeline: The steering committee could be identified/assembled within several months and could within a year establish the sub-groups, determine the dimensions of the assessment, and design the rapid research response mechanism.

Lead Agencies: Consortium of federal agencies that fund NIS R&D,e.g., USDA, NSF, others.
Resource Requirements: $200,000 in new resources would be required to allow participation of members outside of Washington. Additional funds would be required to initiate the assessment and to establish and start-up the sub-groups.

2) Establish new multi-agency federal research initiative to:
Encourage novel integrated R&D that targets high profile, economically important, and/or intransigent NIS,
Include socio-economics considerations,
Perhaps focus on non-crop lands.

Expected Outcomes:
Rapid expansion in fundamental knowledge of specific NIS problems.
Significant increase in number of NIS operational actions and number of NIS controlled.
Reduced economic and environmental losses due to NIS.
Reduced pesticide use and other non-sustainable pest management tactics.
Reduced NIS rates of spread.

Timeline: The new multi-agency competitive grants program could be established and implemented within one year with the first research results within the first two years.

Lead Agencies: Consortium of federal agencies that fund NIS R&D,e.g., USDA, NSF, others.

Resource Requirements: New money - $40 million per year to support competitive grants targeting NIS in terrestrial and aquatic ecosystems

Applies to Research Issues 1-6:

What are our desired outcomes? An understanding of overall invasion biology and prevention and control strategies of at least representative taxa from all groups of biological organisms. INCREASED FUNDING FOR MONITORING AND RESEARCH, AND INCREASED NATIONAL CAPACITY TO RESPOND TO INVASIVES.

What is our evidence for achieving them? Increased ability to conduct NIS risk assessments with a high degree of accuracy (confidence) due to information available; reduced introductions of NIS; better control and reduced spread of NIS.

Where/When/with whom will the program take place? The program should be coordinated by U. S. federal agencies impacted and involved in NIS issues, but actively involve other researchers and stakeholders. The research by necessity will be conducted both within the U.S. and outside of the U.S. in order to study organisms that have already invaded other habitats to glean information about why and how they were able to invade. Research will be needed on organisms in their natural habitats in order to determine their biology such as host range, genetics, physiology, etc. Some of this research should be conducted on species that have already invaded the U.S. Present research (AND MONITORING) efforts need to be expanded and critical new research initiatives started immediately. We need to develop a coordinating committee that can determine research priorities and help researchers obtain funding.

What are the potential challenges to success? Obtaining the funding; building infrastructure for research; establishing and utilizing the official mechanisms for providing funding to selected researchers; obtaining "permission" or cooperation with other governments to conduct research in their countries; AND PROVIDING FUNDS IN A TIMELY FASHION TO ALLOW FOR RAPID RESPONSE.

What resources do we already have? The National Research Council was commissioned by APHIS/PPQ to coordinate a committee to determine how to study and predict invasiveness, i.e. the scientific basis of invasiveness and research areas from which information is needed to predict invasiveness (i.e. arrive, survive, thrive). There are many successful research efforts ongoing at universities, state, private research institutions, and federal laboratories.

Expertise for doing the research? While there are many experts on various NIS that have been identified, others will have to be educated and trained. Infrastructure needs such as containment facilities, equipment, etc. will have to be expanded .

What do we need? Need to build upon present university, state, federal and private research capacity and additional support for critical research gaps including information resources. WE HAVE A STRONG, IMMEDIATE NEED FOR MORE CONTAINMENT (QUARANTINE) AND REARING FACILITIES. WE NEED TO DETECT NIS EARLIER AND DEVELOP THE CAPACITY FOR MORE RAPID RESPONSE.

INFORMATION SHARING/DOCUMENTATION ISSUES

Research on pest species and invasion biology, early detection and control, management of established populations and public outreach have all been hampered by the fragmented state of information systems addressing invasive species. Recent compendia of U.S. invasive species databases have identified over 60 information systems of statewide, national, or international importance directed explicitly toward invasive species issues (e.g., *http://www.nbii.gov/invasive/workshops/proceeds_lv.html)*. At least as many more general biological databases (e.g., museum and herbaria records, restoration project catalogs, ecological monitoring databases, etc.) contain valuable information on invasives. Core information on many species and locales may be found in technical publications, desktop databases of individual researchers or managers, or in paper reports. Unfortunately, because of differences in methods, vocabularies, and data exchange mechanisms, our ability to synthesize these data and apply them to research or management questions is limited. Data elements included go far beyond pure research needs, and include:

- black lists (and potentially white lists)
- directories of experts and organizations
- environmental impact review
- eradication and control projects
- interception records
- keys and visual aides
- laws, regulations, and authorities
- management practices
- monitoring data
- species locations and ranges.

Elements of several of these can be found in most state, national, and international initiatives on invasive species.

Although it may be feasible to consolidate parts of this complex data universe into national clearinghouses, ultimately most should and will remain distributed. This is partially because each addresses rather particular legal mandates or research questions, and will contain a variety of unique attributes dictated by the needs of its particular users. Essentially every active information effort also depends upon local expertise for taxonomy, updates, quality control, and voucher or reference materials. The challenge is to develop standards and protocols so that the shared core information (species names, locations, collections, effective practices, experts, etc.) needed for synthetic national assessments can be reported in a cost-effective and transparent way, while still maintaining local control and responsibility for the fundamental data.

Solutions require both technological and institutional developments. Highly distributed information warehousing and data discovery strategies developed for economic or geophysical data can presumably be adapted to biodiversity data, but their scalability to the heterogeneous platforms and thousands of environmental attributes treated in ecological and agricultural data settings remains to be demonstrated. There seems to be widespread agreement that Web-enabled XML technologies can be adapted to these uses, but actual applications are mostly at the demonstration stages (e.g., Species Analyst, *www.chilpolte,ukan.edu*). Presumably multiple portals to this corpus of information could be developed. For example, one application might "crawl" species occurrence databases to detect new records and range extension to provide early

alerts, whereas quite a different application might poll the same databases for help materials and images for species identification.

Key to any successful data integration is the development of shared "controlled vocabularies" (or "thesauri"), so that core data elements are called the same thing, and coded in the same way, when shared among multiple sources. Common vocabularies permit searchable classifications (through "metatagging") of quite heterogeneous data types, including databases, images, text documents, and models. Among key vocabulary elements, the most work has gone into species taxonomy, and it is reasonable to think that standards programs such as the Integrated Taxonomic Information System (ITIS, with potential international extensions to such cooperators as Species 2000 and the proposed Global Biodiversity Information Facility, GBIF) can provide a framework for common reporting of species names. A similarly standardized treatment of laws, regulations, and authorities related to invasive species is presumably feasible, but not currently available. Geolocations, chemical types, soils, habitat types, and field methods are progressively less standardized and more difficult to classify. However, institutional as well as technological methods to enable "keepers of the codes" will be necessary if large numbers of data centers are to exchange data in an automatic and standardized way.

First steps to develop standardized access to invasive species information are underway at state (e.g., CERES in California – *ceres.ca.gov*, INVADERS, *http://invader.dbs.umt.edu/,* in the Pacific Northwest), national (*invasivespecies.gov*, *http://www.nbii.gov/invasive/*) and international scales (e.g., GISP, IABIN). However, they have not formalized controlled vocabularies internally, much less among themselves, making distributed searching and information discovery difficult.

Outstanding information systems research issues include:

- Structures for controlled vocabularies – for example, treatment of synonyms, obsolete usages, undetermined species identifications, etc., in taxonomic databases
- Scalability -- development and maintenance of coordinated data reporting structures (maybe XML document type definitions) and controlled vocabularies over hundreds of sites and users
- Metadata for QA/QC of data inputs, particularly from non-traditional sources such as volunteer groups and schools
- Natural language access – can language patterns in documents and other data elements be used to classify and retrieve them
- Models – real-time assessment of ranges, risks, or effectiveness of potential control methodologies, extrapolating experiences from heterogeneous sources
- Wireless or other field-enabled access to identification and help materials

Increasing access to and sharing of information about all aspects of invasive species management is one of the central themes of this National IS Management Plan. This includes information relating to IS taxonomy and identification, risk assessments, invasions and distributions, biology, control and management, laws and regulations, education and outreach. It includes information collected and maintained by many different agencies, organizations, and individuals around the U.S. and throughout the world. It includes data sets, books, technical reports, and journal

articles; maps; photos and videos; lists of experts; museum specimens, and many other forms of data and information products, much of which may not yet be available in any digital or computer-accessible form.

What is needed is an overall approach or framework that will 1) link all of this existing information together into a distributed "IS information network;" 2) make it possible for interested users of all types (from scientists to elementary school students) to quickly find all the pertinent IS information they need on a specific subject or question, even when the information needed resides at multiple different sources; and 3) provide a common infrastructure (i.e., data and information standards and guidelines) so that as "new" IS data and information is collected and produced it can continue to be readily incorporated into the national network.

Implementation of the following recommendations would lead to the development of this national IS information system—this system would thus support ALL of the aspects of the National Management Plan, ranging from research and monitoring to communication and outreach.

Information/documentation issues vital to the prevention and control of NIS have been divided into five major areas:

Issue 1: Inventory and Assessment of Invasive Species Information Resources

Reliable information is the foundation for sound decision-making. Accurate and comprehensive information on the identification, occurrence, distribution, and impacts of invasive species in the U.S. is the crucial starting point for effectively addressing the issue. We do not know the full range of information currently available, the form and quality of this data, and conversely, what information is missing.

Invasive species information is collected and maintained by numerous agencies and organizations in scattered databases focused on selected taxonomic groups, certain types of land use (agriculture, forestry, wetlands, natural areas), and occurring in particular states, geographical regions, or on lands managed by an agency or organization. Much of this data is stored electronically using varying types of formats and a potentially large amount is not yet available electronically.

Suggested Actions:

- Identify lead agencies and organizations that are gathering and using invasive species information and developing invasive species databases and web sites.

- With the assistance of identified lead agencies and organizations, conduct a comprehensive survey of existing invasive species information resources in the U.S. and internationally.

- Organize and summarize existing information by taxonomic group, land use, land ownership, geographical region, and other useful categories.

- Identify priority data sets and sources.

- Identify information gaps and overlapping or duplicative information. Make recommendations on how to address these deficiencies and problems. For example, identify which agencies or organizations are best suited to manage information on various taxa.

- Evaluate the quality and reliability of existing information.

- Investigate what resources (i.e., funding and staffing) are invested, or will be invested, in information management by each agency or organization.

Desired Outcomes:

1) Completion of a comprehensive survey that identifies all existing information resources on invasive species in the U.S. and internationally.

2) Preparation of a report summarizing the status of existing information, including an assessment that identifies data overlap and gaps and recommendations for addressing these problems.

Expected Outcomes:

Effective dissemination of a comprehensive survey will be facilitated through cooperation between government and non-governmental partners working on invasive species, especially those involved with databases. Two major surveys were recently conducted by the U.S. Geological Survey in 1997 (Non-Indigenous Plants) and the C.V. Riley Memorial Foundation and three federal agencies in 1998 (Invasive Species Databases), to inventory non-indigenous species information resources in the U.S. The published results of these surveys serve as a valuable starting point and will be useful in developing a comprehensive national survey.

The U.S. Geological Survey (Biological Resources Division) and the U.S. Department of Agriculture are appropriate lead agencies for coordinating a national survey on invasive species information, for natural and managed lands, respectively. These lead agencies should design and conduct the survey in cooperation with the following non-governmental organizations: the Association for Biodiversity Information, The Nature Conservancy's Wildland Weeds Management and Research Program, the National Association of Exotic Pest Plant Councils, and the Plant Conservation Alliance. The invasive species taxonomic and geographic focus of each is described below.

Invasive Species Affecting Agricultural Systems:

- **The U.S. Department of Agriculture** is responsible for managing native and non-indigenous species on national forests and agricultural lands and for preventing the

introduction of regulated species into the U.S. The USDA currently serves as the lead agency for information on pest insects, plants, and pathogens affecting agricultural crops and national forests and for research on biological control agents for agricultural pests. The USDA can ensure inclusion of all relevant federal, state, and local governmental agencies and relevant non-governmental organizations (e.g., the Weed Science Society of America) involved with agriculture and forestry in the national survey.

Invasive Species Affecting Aquatic Ecosystems:

- **The U.S. Geological Survey's Biological Resources Division (BRD)** supports biological science research on native and non-indigenous species on public lands administered by the U.S. Department of the Interior. The BRD can ensure inclusion of all relevant federal agencies of the departments of Commerce, Defense, Education, Transportation, and Interior the Environmental Protection Agency, and others, in the national survey, and coverage of invasive species of animals and plants of managed (agricultural) and natural lands. The BRD is currently the lead federal agency for information on non-indigenous aquatic species.

Invasive Organisms Affecting Aquatic and Terrestrial Ecosystems:

- The Association for Biodiversity Information (ABI), a recent offshoot of The Nature Conservancy, maintains centralized, taxonomically reconciled information on the classification, distribution, and status of about 40,000 species of native and exotic plants, animals, and other organisms of the U.S. and Canada (and numerous other species of Latin America and the Caribbean region). ABI works with the state Natural Heritage Programs and international Conservation Data Centers to maintain locality-specific information on occurrences of rare native species and invasive species that threaten their habitats.

Invasive Plants Affecting Aquatic and Terrestrial Ecosystems:

- **The Nature Conservancy's Wildland Weeds Management and Research Program** is focused on identification, monitoring, and management of invasive plants in natural areas or wildlands.

- **The National Association of Exotic Pest Plant Councils (NA-EPPC)** is a federation of non-profit state and regional councils organized to address invasive plants affecting natural areas in the U.S. These councils work at the state or regional level and involve as many stakeholders as possible (i.e., agriculture, parks, preserves, and other public lands managers, the horticulture industry, cooperative extension, gardening community, etc.), to ensure effective communication, information sharing, and coordinated actions. EPPCs identify and prioritize invasive plant species, develop effective species management strategies, conduct research on invasive species, and produce public education materials. Councils, listed below, have been established along the east and west coasts, but a large gap exists in the central section of the U.S. While much information is available on invasive plants in this region of the country, it is scattered among a variety of agencies and organizations. The NA-EPPC is attempting to fill this gap by encouraging existing groups to work together to share knowledge, management techniques, and resources. Increased cooperation with Canada and Mexico and other countries is also planned.

1. California Exotic Pest Plant Council, est. 1990
2. Florida Exotic Pest Plant Council, est. 1985
3. Mid-Atlantic Exotic Pest Plant Council, est. in 1999. Includes Delaware, Maryland, New Jersey, Pennsylvania, Virginia, West Virginia, and the District of Columbia
4. Pacific Northwest Exotic Pest Plant Council, est. in 1996? Includes
5. Southeast Exotic Pest Plant Council, est. in 1999. Includes Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia.

The Plant Conservation Alliance (PCA), previously the Native Plant Conservation Alliance, was established by a Memorandum of Understanding signed by a committee of ten federal agencies in 1994 (and renewed in 1999). The PCA is governed by the Federal Native Plant Conservation Committee and has identified as its mission the conservation, protection and restoration of native plants and natural ecosystems in the U.S. In addition to a well established and expanding network of federal agency contacts, the PCA has over 160 non-federal cooperators, including academic institutions, arboreta, botanic gardens, exotic pest plant councils (EPPCs), the horticulture industry, native plant societies, state and local government agencies, state natural heritage programs. Several major supporters include the Association for Biodiversity Information (ABI), the Lady Bird Johnson Wildflower Research Center, the Natural Areas Association, The Nature Conservancy (TNC), and the Society for Ecological Restoration. Working groups of the PCA cover alien plants, medicinal plants, pollinators, public education and outreach, and ecosystem restoration.

Since 1995, the PCA's Alien Plant Working Group (APWG) has been active in compiling information on invasive plants nationally and internationally, making it available on the web, and linking to as many existing organizations as possible. The APWG is developing a global network, called the "World-Wide Weed Web" (Weed Web), to identify all governmental and non-governmental partners from the local to the international level that are involved with or significantly affected by invasive plants. A selection of agencies and organizations excerpted from the Weed Web could serve as a starting point for a Survey Recipients List (see "Potential Invasive Species Information Survey Recipients" at end of this section).

Location of Program: The survey will take place at the national level but include international information, and attempt to reach as many relevant agencies, organizations and individuals as possible that are compiling and storing data on invasive species.

Timeline: Development of the survey and list of recipients can begin as soon as the NISC has identified and approved an interagency survey team and funding is made available. One year is probably the minimum amount of time needed to complete the entire project from survey development to reporting of results.

Lead Agencies: This project should involve all relevant agencies, organizations, institutions and individuals working on or significantly affected by invasive species. Many of these have been identified in item 2 above.

Potential Challenges: Some of the challenges to completing a successful survey are:

- Getting full and timely participation of the various recipients to complete surveys in a timely manner. Because this information is critical to the development of the national invasive species information system, it needs to be conducted within a short time frame without jeopardizing the quality or quantity of information obtained.

- Achieving thorough, comprehensive coverage of information covering all taxonomic groups, land uses, geographical areas, and natural and political boundaries.

- Creating a management structure for the inventory.

- Obtaining adequate funding for the inventory.

Resource Requirements: Some of the many excellent sources of information on invasive species currently available on the internet include:

Aquatic Species

U.S. Army Corps of Engineers, Aquatic Plant Control Operations Support Center http://www.saj.usace.army.mil/conops/apc/apc_page.html Provides corps-wide expertise in the operational aspects of aquatic plant management and includes a searchable database, management methodologies, publications and links.

University of Florida, Center for Aquatic and Invasive Plants, Aquatic, Wetland and Invasive Plant Information Retrieval System (APIRS). http://aquat1.ifas.ufl.edu Provides a computerized bibliographic database (Copyright University of Florida, 2000) devoted to freshwater aquatic and wetland plants as well as terrestrial and aquatic invasive plants. The database includes citations for more than 51,000 research articles, books, and reports about aquatic plant ecology, physiology, utilization and control.

U.S. Geological Survey, Nonindigenous Aquatic Species Information Resource. http://nas.er.usgs.gov/ Provides lists of noniidigenous plant and animal species impacting aquatic habitats, photographs, bibliographies, species fact sheets, and other information.

Terrestrial Plants and Animals (plus some aquatic)

Alien Plant Working Group - "Weeds Gone Wild: Alien Plant Invaders of Natural Areas". http://www.nps.gov/plants/alien Provides national list and database of over 800 invasive plant species affecting natural ecosystems in U.S. states, territories and possessions; illustrated fact sheets with identification, management, suggested alternative plants, and other information; links to over 85 national and international invasive species sites; downloadable slide presentation on invasive plants; selected press and publications; theme song; and other information.

Association for Biodiversity Information (ABI) NatureServe. Web site – under development. Provides databases of classification, state distribution, native/exotic status, and selected other information for all native U.S. and Canadian species of vascular plants, vertebrate animals, and selected other groups of invertebrates and nonvascular plants.

Biota of North America Program (BONAP). http://www.bonap.org/ Developing a unified digital system for assessing the North American biota. The BONAP database now includes data for all vascular plants and vertebrate species (native, naturalized, and adventive) of North America, north of Mexico, with taxonomic, nomenclatural, and biogeographic data.

California Exotic Pest Plant Council. http://www.caleppc.org/ Provides list of invasive plant species affecting natural areas in California, photographs, invasive plant links, and other information.

Colorado Plateau Field Station Southwest Exotic Plant Mapping Program.
http://www.usgs.nau.edu/swemp/ A program designed to develop a regional database of exotic plant distributions for the southwest (which consists of Arizona, New Mexico and Colorado Plateau portions of Utah and Colorado).

Ecoport. http://www.ecoport.org Provides data on species worldwide, with emphasis on invasive insects and plant diseases. (Formerly, the FAO's Global Plant and Pest Information System).

Florida Exotic Pest Plant Council. http://www.fleppc.org/ Provides prioritized list of species affecting natural ecosystems in Florida, plant management guidance, links, and other information.

Hawaii Biological Survey. http://www.hbs.bishopmuseum.org Provides a large amount of information on invasive species in Hawaii, mostly in searchable databases; provides much of the underlying information for the Hawaiian Ecosystems at Risk web site.

Hawaiian Ecosystems at Risk (HEAR) Project. http://www.hear.org Provides list of insect, plant and other species affecting natural ecosystems in Hawaii, large number of photographs, management guidance, and links to other sites.

International Union for the Conservation of Nature (IUCN) Invasive Species Specialist Group.
http://www.issg.org Provides a pilot database on invasive species for the Global Invasive Species Program (GISP).

Mid-Atlantic Exotic Pest Plant Council. http://www.webriver.com/tn-eppc/maeppc.htm Provides a (draft) list of invasive plant species affecting natural ecosystems in the Mid-Atlantic region of the U.S. (DE, MD, NJ, PA, VA, WV, and the District of Columbia), invasive plant identification and plant control and site restoration guidance, public education materials, and other information, and maintains a list-server for members. Site currently under development.

Pacific Northwest Exotic Pest Plant Council. http://www.wnps.org/eppclet.html Provides ranked list of problematic invasive exotic plant species for Oregon and Washington, and other information.

Southeast Exotic Pest Plant Council (SE-EPPC): http://www http://www.webriver.com/tn-eppc/ Provides list of species and management guidance for invasive plants impacting natural ecosystems ~~areas~~ in the Southeast U.S., including a published manual on identification and management of 20 highly invasive species, links to state EPPCs (AL, FL, GA, KY, LA, MS, NC, SC, TN, VA) and other invasive plant sites, and other information.

The Nature Conservancy, Wildland Invasive Species Program: http://tncweeds.ucdavis.edu/ Provides a list and searchable database of invasive plant species affecting preserves of The Nature Conservancy and other natural lands in the U.S., photographs, management guidance, plant pest alerts, links, and much other information. Also maintains a national list-server on invasive plants.

U.S. Fish and Wildlife Service, Invasive Species Program. http://invasives.fws.gov/ Provides list of invasive plant species impacting prairie ecosystems in the northern prairie region.

University of Florida, Institute of Food and Agricultural Services: http://www… Provides a list of invasive plant species… , photographs, management guidance, links, public education.

University of Montana, INVADERS Database System. http://www… Provides species lists, fact sheets, photographs, and other information on noxious and invasive plant species in the Northwestern U.S. (ID, OR, MO,WA, WY)

U.S. Department of Agriculture, National Agricultural Pest Information System. http://www... Provides information on insects, plants and pathogens affecting croplands, links.

Additional Resources Needed: In addition to funding to support agencies to compile comprehensive data on invasive organisms in the U.S., funding is desperately needed to support the hiring of additional taxonomists, especially botanists, entomologists, and invertebrate zoologists, to ensure accurate identification of species, both native and exotic. Additional taxonomists should be located in federal land management agencies such as the U.S. Department of Interior (e.g., Bureau of Land Management, Fish and Wildlife Service, Geological Survey, National Park Service, U.S. Department of Agriculture (e.g., Agricultural Research Service, Forest Service..), federal institutions like the Smithsonian Institution (e.g., National Museum of Natural History, Smithsonian Ecological Services Laboratory), and private institutions such as the American Museum of Natural History, the Carnegie Institute, and others.

Project Implementation: A national invasive species information survey could be conducted largely through the internet, supplemented as needed with traditional methods (i.e., mailings, meetings, workshops). Organizers of the 1997 and 1998 invasive species database workshops should be enlisted to help with the development and coordination of the survey. If needed, one or more workshops could be organized, at the national or regional level, and possibly as special sessions during annual meetings or conferences of organizations like the American Institute of Biological Sciences, the Botanical Society of America, the Ecological Society of America, the Entomological Society of America, the National Association of Exotic Pest Plant Councils, the Natural Areas Association, the Plant Conservation Alliance, the Society for Conservation Biology, the Society for Ecological Restoration, the Weed Science Society of America and others

Funding should be obtained to hire a coordinator to develop and implement the survey and to report on its findings. First, a comprehensive list of survey recipients needs to be prepared, preferably by a small group of individuals from various governmental entities and non-governmental organizations. Next, a survey needs to be crafted that will ensure adequate reporting of invasive species information. Some information and questions that should be included in the survey are:

1. Agency or organization:
2. Invasive species program manager or project contact:
3. Which taxonomic group(s) does your system include?
4. Which geographical or ecological region(s), and political boundaries are covered?
5. Which land uses (e.g., agricultural, natural ecosystems) are included?
6. Is future expansion planned to include additional taxa, ecological or geographical regions or political boundaries or other? If so, explain:
7. What is the geographic coverage of your information?
8. What form is your information in? (A list, spreadsheet, database)
9. What software is being used?
10. Is your information available electronically, via the internet, or hard copy only?

11. What resources are needed to complete an inventory of invasive species by your agency or organization?

Priority: Survey of Existing NIS Information Resources

Short-term Actions: Conduct a survey of existing information resources on invasive species in the U.S. and internationally; summarize and assess status of information. **Longer-term Actions:** Evaluate quality and reliability of information; identify data gaps; develop a plan to address missing information and eliminate unnecessary redundancies.

Expected Outcome: ?

Lead Agencies: USDA, DOI/USGS

Timeline: 18 months

Resources Requirements: $200K

Issue 2: National Invasive Species Information System

Our ability to effectively implement a coordinated national response to NIS is severely limited by the lack of a coordinated national framework/network for invasive species information. A distributed, national invasive species information system is needed that increases access to and integration/inter-operability of existing information from many sources to many different types of audiences/stakeholders.

Suggested Actions: Plan for the development of a national invasive species information system.

What are our desired outcomes? Currently, data and information relating to invasive species is widely distributed among by government agencies at all levels, academic scientists, non-government organizations, private industry and others throughout the U.S. and in other countries. The most effective way to take advantage of all these different existing sources of information is to use current Internet technologies to create a distributed electronic network that builds on and links together links all of this data and information together into a distributed federation. In this way, interested users can easily search for and find data and information on a given species or a given topic area or question and be able to access multiple distributed data and information sources.

The national system will not be a new centralized data repository, nor will it replace or supersede any existing data and information collection, management or dissemination activities of individual agencies or institutions. We don't need to develop a single, huge centralized "data repository," because the technology now exists to access data and information across multiple sources. This approach will take greater advantage of the hundreds, if not thousands, of different IS data and information sources, without forcing them to lose their individual identities, their individual focus areas, individual agency mission responsibilities, and individual strengths. There would be little or no buy-in from all the interested IS data and information producers

(government and non-government) to an imposed centralized approach. In addition, the distributed data federation approach is consistent with the approaches for IS information sharing that are being developed at the regional and global levels (e.g., the Global Invasive Species Information Programme).

Thus, the proposed national IS information system will provide the framework or infrastructure that:

- helps to make it easier to locate and retrieve specific IS information from the many different source agencies and institutions;
- makes it possible to integrate or link together information from two or more different sources, even when this information is in disparate forms or formats;
- is flexible and open-ended so that newly collected information can be continually incorporated;
- supports all the data and information collection, management, sharing, and analysis needs of the National Invasive Species Management Plan, including data and information on laws, policies and regulations; research and monitoring; control and management; outreach and education, and international information sharing;
- provides easy access to a variety of analytical tools (such as ecological models, GIS applications, visualization and simulation tools, decision support tools) that allow users to apply the data and information to answer questions, support management decisions, etc.;
- provides easy access for all "categories" of interested users and stakeholders, including scientists, resource managers, policy and decision makers, educators and students, and the general public, by providing specially designed or tailored views or portals into the information for different groups; different agencies and organizations can also provide their own tailored access portals into the national system—thus giving them a greater sense of "ownership" and participation in the national IS program;
- is primarily Internet-based, but also accommodates alternative (non-Internet) inputs and outputs; and
- provides a strong U.S. linkage to related invasive species information networks at the international level. The overall result will be to add value and utility to the entire existing body of data and information on invasives - by providing the underlying framework that "knits" all of these information sources together.

What is our evidence for achieving them? When the national invasive species information system is fully functional, it will be possible for anyone to access the system through a single recognizable "gateway" or portal, to quickly and easily locate pertinent data and information from multiple, distributed sources (e.g., on a given question or topic or species), to combine or integrate the information from different sources in a meaningful way, and to readily apply the information (using appropriate analytical tools) to answer a particular question.

Where will the program take place? This will be a national-level effort, because it needs to involve and engage the many different sources of data and information that are distributed across the U.S. and, in some cases, internationally. The planning and overall coordination for development of the system should be led by the federal agencies which already have significant

investments and activities in invasive species information collection, management and dissemination (e.g. DOI, USDA, DOC, DOD).

When will the program take place? Work on a new interagency invasive species web site (www.invasivespecies.gov) is already beginning in FY 2000 as a joint activity of USDA and DOI/USGS. Planning can for full implementation of the national IS information system can begin in FY2001, assuming the key federal agencies involved have funding available from FY2001 increase requests in this area. Development of the system should begin in FY2002.

With whom will we work? We will work with the broad communities of information suppliers/providers as well as the information customers/users. Planning and development of the national information system will require that we work with all of the agencies and organizations (government and non-government) that collect, manage and maintain, and disseminate invasive species information in order to ensure that their information "holdings" are effectively and appropriately (e.g., some information may be sensitive or in some way restricted from full access) included or represented within the distributed national framework. At the same time, the goal will be to impose as minimal a burden as possible on these information sources, i.e., by minimizing the type and extent of additional documentation or re-configuration needed to make the different types of source information accessible as part of the larger, distributed system. We also will consult and work with all existing and potential "customers" or users of the information by involving them in design and development of the system. This will ensure that the system can meet the requirements of various customer/user groups (scientists, resource managers and decision makers, private industry, general public, etc.) in terms of types of data and information available, ease of access and use, types of analytical tools and applications available; etc.

What are the potential challenges to success?

- Existing data and information is widely distributed, and is in many different forms and formats (including much potentially valuable information that may not be electronically accessible);
- data and information also vary widely in terms of quality, verification, documentation (metadata), etc.;
- individual agencies and organizations generally lack sufficient resources (funding and staffing) to effectively document, maintain and archive, and electronically serve their respective data and information holdings;
- there are currently no funding resources identified and allocated at the national level (i.e., through one or more of the key Federal agency participants) to support the work needed to design and develop the needed national system framework or infrastructure;
- additional computer/information science R&D may be needed to support particular challenges/requirements of the national system.

What resources do we already have?

- A wealth of existing data and information exists already;
- work has begun , through a partnership between USGS and the National Agricultural Library, to develop an interagency web site (www.invasivespecies.gov) that could serve as the Internet "gateway" into the national invasive species information system;

- the National Biological Information Infrastructure (NBII) provides a distributed, Internet-based framework for biological data and information sharing. It is anticipated that the proposed national invasive species information system could utilize/emulate many of the features and capabilities of the NBII (architecture, data and metadata standards, technologies, etc.). In this way, the invasive species information system could essentially function as an integral component of the overall NBII biodiversity data network.

What additional resources do we need? Additional funding is needed for individual agencies and organizations that collect and maintain invasive species information - so that they can appropriately "prepare" and maintain their respective information holdings so that they are as accessible as possible through the overall national framework.

- This may require funding for documentation (metadata development, indexing and cataloging of data sets and information products) and additional data management resources (electronic serving, archiving, etc.). Funds are also needed to support the design, development, and continued operation of the national system itself . This includes funding for system design, funding for development of standards and guidelines; funding for needed computer/information science research and development (e.g., new tools to make disparate data interoperable, new tools to rapidly digitize information that is not currently electronic, etc.); and funding for operation and enhancement of the national system's Internet "gateway" site. It is estimated that approximately $1 million/year for 2 years would be required to support the initial design and development of the system, and that continued operation and regular enhancement of the system (i.e., to incorporate new technologies and capabilities as needed) would require between $250,000-500,000/year.

What are the steps to project completion?

1. FY2000 and 2001: establish working group/task force to design "national invasive species information system" (i.e., to describe system requirements and capabilities from both a user/stakeholder perspective and a technical perspective). Note that Riley Memorial Foundation is already organizing/holding stakeholder workshops that can provide excellent starting point for this step.
2. 2000 and 2001: identify existing funding and staffing resources available from various government and non-government participants.
3. 2001: identify what aspects or components of existing national-level data networks (such as the NBII or NSDI) can be adopted/utilized as parts of the backbone of the national system.
4. 2001: identify (and acquire?) additional resources required to develop system (funding, staffing, technological).
5. 2002: begin system development.

Priority: Expand New Interagency Web Site

Suggested Action: Expand development of the new interagency web site (www. invasivespecies.gov) initiated by USDA and DOI/USGS. This site will be a key "gateway" into existing IS data and information from government agencies and non-government organizations and can be the initial cornerstone of the national IS information system.

Expected Outcome & Timeline: This site is already underdevelopment and should continue to be expanded over the next 6-12 months, by adding additional materials, adding and updating links to other existing sources, and adding new functionalities to the web site.

Lead agencies: USDA (ARS) and DOI (USGS).

Resource Requirements: Additional funding is needed to support the continued development of this site (estimated cost: $150,000/year for web site operation and maintenance).

Issue 3: Information Guidelines and Standards

Our ability to support more coordinated collection, management, dissemination and exchange, and application of invasive species information across many agencies and organizations is limited by a lack of agreed upon information guidelines and standards. This includes, but is not necessarily limited to standards for data collection, reporting, and verification; taxonomic identification standards; and information accessibility and sharing guidelines.

Suggested Actions: 1) Identify the needed information standards and guidelines that will effectively support the National Invasive Species Management Plan. 2) Next, specify which of these needed standards and guidelines are already available in some form from which they could be readily adopted/adapted for use in the National Invasive Species Management program. 3) Identify which needed standards and guidelines do NOT already exist and will thus need to be developed. 4) Develop these "missing" guidelines and standards.

What are our desired outcomes? The desired outcome in general is a set of guidelines and standards that allow for flexibility among different information sources while providing a common level for interoperability. Standards and guidelines need to be developed that can be effectively applied to two basic types of IS information: 1) "legacy" data and information that already exists and is in many different digital and non-digital formats; and 2) "new" data and information that will be gathered and managed using the agreed upon standards and guidelines.

Overall policies or guidelines are needed that are mutually agreeable to the entire IS community regarding what types of data will be submitted and catalogued, what types of data will be shared by whom and with whom, what data would have unrestricted access, whether data are verified, etc. This would also include policies for "reporting" new invasions in order to maintain consistency and an appropriate level of quality and inter-compatibility.

Standards and guidelines should be developed with input from potential data-gatherers, managers of the data, and users and should be communicated widely in an effective manner so that the highest number of information providers will utilize them.

IS information standards and guidelines are needed in the following major areas:

Data/Information Collection: This area includes standards and guidelines for documentation/reporting of invasive species occurrences (what information should be reported to effectively document an occurrence); taxonomic identification (taxonomy and nomenclature);

and quality control and verification (to verify reports, including standards for voucher specimens to verify identifications and to ensure accessioning of voucher material to collections (records are worthless without a specimen).

Data/Information Cataloging and Discovery: This area includes standards and guidelines for documenting, describing, or cataloging data sets, databases, technical reports, web sites, and other information sources (i.e., metadata) so that these sources can be effectively discovered, retrieved, and used. This documentation includes information about the databases such as who collected the data, when, how, data quality controls, etc. Also includes taxonomic identification standards and spatial data location standards, because two of the most important ways that people will search for and select data and specific invasive species information will be on taxon and on spatial location. Also includes development of controlled vocabularies (thesauri) for invasive species information. Controlled vocabularies can be used to index and catalog data and information sources (data sets, web sites, etc.) and can be used in search engines to help zero in more effectively on particular target data sources.

Data/Information Interoperability: This area includes standards and guidelines for actually integrating data or information from two or more different sources together in order to conduct more advanced analyses, etc. Data interoperability involves "content" standards (such as taxonomic identification standards and spatial data location standards) and more technologically oriented "structural" standards (such as XML, see Issue #4). This area also includes the necessary information standards that will make it possible to more consistently integrate invasive species data and information with other types of data and information, including other environmental information on land cover, land use, hydrography, soils, climate, etc.) and socio-economic information on population, agricultural practices, transportation, etc. (see also Issue 5).

What is our evidence for achieving them? Our best evidence, or performance indicator, will be the ability of all users to access a wide variety of information in the format that best suits their needs.

- Concrete evidence would be the implementation of the needed standards and guidelines as described above and the widespread acceptance of those standards by those producing and managing data and those searching for and using data.
- Existing (legacy) data and information will be more easily located, retrieved and integrated with other data and information, thus increasing the utility of our existing IS information base. And new collection and reporting of IS data and information will be done more consistently across agencies and organizations.
- The ability to access information and utilize it in making risk-based safeguarding and management decisions will result in fewer NIS becoming introduced in the U.S.
- Additionally, if we have achieved our goals this information will allow for utilizing the data to make management decisions on controlling NIS and re-establishing habitats damaged due to NIS.

Where will the program take place? The setting of guidelines and standards would be a national-level effort in order to gain input from a wide variety of sources, including government, industry, academia, and other stakeholders who might be providing data, managing the data, or

utilizing the information. The development of specific guidelines and standards should be coordinated by Federal agencies that are active in or will rely on invasive species information (e.g. DOI, USDA, DOC, DOD).

When will the program take place? Development of the comprehensive list of needed standards and guidelines and identification of which of the needed standards and guidelines already exist and can be readily adopted or adapted for IS use can begin in FY 2000-2001. Beginning in FY 2001, work can begin on development of the key "missing" standards and guidelines, i.e., those which do not already exist. Increased support for continued operation and enhancement of the Integrated Taxonomic Information System (ITIS) can begin in FY 2001. If data on scientific and common names for all known invasive species in U.S. could be entered into the ITIS system, it could then serve as a standard, online reference for species names (i.e., to relate different names for the same species together).

With whom will you work? These guidelines and standards will be developed with input from a wide variety of sources including information technology personnel as well as those that gather the data, enter the data, and utilize the data. Broad input will allow us to determine what standards and guidelines are needed, which have worked in the past, and what are actually feasible if we are to have a usable national information system. Input should be obtained from personnel in government agencies, universities, industry, NGO's, international organizations, as well as private citizens and other stakeholders.

What are the potential challenges to success? One of the first challenges will be coming to an agreement on a set of guidelines and standards. Once these are established we are still likely to face resistance to actually using the guidelines and standards. Some database "owners" may be territorial about their sharing their information without some control over it. Communicating the guidelines and standards widely will be essential, and may be challenging. Costs will be a challenge in that there will be costs to develop the guidelines and standards, but also because there will be costs to agencies to utilize and implement them, and this money is not presently allocated.

What resources do we already have? As part of the IS Management Plan, information needs will be determined, currently available sources of information will be identified, and additional needs and priorities established. Available sources of information can be evaluated as to the quality of information that they contain, their flexibility, and their utility to a variety of users. Based on that analysis, information can be gathered from the developers of select databases to determine what types of standards and guidelines were used in developing those successful databases, as well as what didn't work. Additionally, users of information can provide input as to what makes a particular source of information useful. These activities would provide a wealth of information on what types of standards and guidelines have worked and would provide a basis for establishing guidelines and standards for this Management Plan.

Several Federal agencies (USDA, DOI, DOC, EPA, SI, NSF) are supporting the development and operation of the Integrated Taxonomic Information System (ITIS, www.itis.usda.gov) which provides online access to scientific names, synonyms, common names and taxonomy for North American species. ITIS is also linking with and providing data into related global-level

taxonomic information systems (primarily Species 2000). More funding support for ITIS could be used to add and maintain data on scientific and common names for all invasive species in U.S.

The Federal Geographic Data Committee is an existing interagency group supporting development of data standards, including an existing Federal standard for geospatial metadata (FGDC Content Standard for Digital Geospatial Metadata) and an existing Federal standard for biological metadata (Biological Data Profile of the FGDC Metadata Standard). The FGDC has an existing sub-group that focuses on biological data standards (FGDC Biological Data Working Group) which could be tasked to help coordinate the IS standards development effort.

Several other sources of data structure standards and guidelines have been developed including Government Information Locator protocol (GILS www.gils.org) which provides basic, high level, cataloging elements and the Library of Congress' USMARC bibliographic database. Data protocols have also been developed under the Clearinghouse Mechanism of the Convention on Biodiversity.

What additional resources do we need? Additional funding is needed for developing and then implementing (applying) the needed guidelines and standards. This would be part of the overall information planning and development process which would require at least $1 million/year.

What are the steps to project completion? Establish an interagency IS information standards and guidelines group that would, in general, detail the standards and guidelines that are needed, coordinate these efforts, and delegate responsibility for the development and implementation of individual standards and guidelines to appropriate agencies or organizations. (Possibly the FGDC Biological Data Working Group could fulfill this role??)

Specifically, this group would coordinate and oversee the following actions:

- Develop the comprehensive list of information standards and guidelines which are needed to implement the National IS Management Plan.
- Identify any existing information standards and guidelines which can be adopted and/or adapted as appropriate to meet some of the required needs. Document and "endorse" these existing standards and guidelines as being part of the National IS Management program and communicate them to all stakeholders.
- Identify and prioritize "gaps," i.e., information standards and guidelines that need to be developed.
- Detail costs and staffing resources required to develop the needed standards and guidelines and to implement within each agency or other group.
- Support development of needed standards and guidelines by appropriate agencies, organizations, and/or interagency groups.
- Document and endorse these new standards and guidelines as being part of the National IS Management program and communicate them to the appropriate stakeholders for their implementation.

Priority – Develop Invasive Species Information Standards and Guidelines

Suggested Action 1: Develop the comprehensive list of exactly what IS information standards and guidelines are needed**.**

Expected Outcome: A compilation of IS information standards and guidelines.

Timeline: This could be done within 1 year.

Lead Agencies: DOI and USDA could possibly take joint responsibility for developing this list, possibly working through the existing FGDC Biological Data Working Group (?) or through a contract.

Resource Requirements: Estimated cost for compiling this list: less than $100,000.

Suggested Action 2: Once the above list is compiled, identify which of the needed information standards and guidelines already exist in some form and thus could be adopted or adapted for use in the National IS program..

Expected Outcome: Establish a set of IS information standards and guidelines.

Timeline: This could be done within 6 months of finishing the comprehensive list of needed standards, possibly as an extension of the same project or contract.

Lead Agencies: As above.

Resource Requirements: Estimated cost: $50,000.

Suggested Action 3: Access to a credible and dynamic list of names of invasive species (including all scientific synonyms and vernacular names) is of fundamental importance to this enterprise. Short-term action is needed (beginning in FY 2001) for the existing ITIS system, specifically to add and maintain scientific and vernacular names for all known invasives in the U.S. within the ITIS database. ITIS could then act as the online reference system to relate and cross-reference species names across all different IS systems and databases. Longer-term action is then needed to enable agencies and organizations that collect and maintain IS data and information to link their species names to the species names in the ITIS database.

Expected Outcome: ITIS established as the online reference system to relate and cross-reference species names across all different IS systems and databases.

Timeline: Short term action beginning FY 2001.

Lead Agencies: USDA, DOI, EPA, DOC, and SI.

Resource Requirements: Estimated cost: $100,000.

Issue 4: Invasive Species Information Research and Development

Additional research and development is needed to use the computer/information science capabilities that would support a fully inter-operable and accessible invasive species information system.

Suggested Actions:

- Integration/inter-operability of diverse, widely distributed data and information sources using web-enabled approaches (XML, CORBA, COM). This requires common data definitions and schemata at least at the web-interface level;
- efficient technologies for converting significant non-electronic information sources into electronic/digital formats (automated OCR, pdf files, html and pdf indexing);
- providing different users/audiences with individualized/tailored access and retrieval capabilities(database of clients, cookies, intelligent searches, customizable search software); and
- providing more advanced remote decision support and analytical capabilities (visualizations, simulations, GIS, integrated search and reporting tools).

What are our desired outcomes?

- Rapid access to remote information,
- integration of information from multiple sources,
- information in formats most useful to diverse stakeholder groups, and
- science-based decisions.

What is our evidence for achieving them? Industry has already demonstrated the feasibility of using current emergent Internet technology to provide all of the above outcomes. There are also examples from other related focus areas (e.g., pest management) where this has been accomplished within a government/university/industry partnership model (see www.reeusda.gov/nipmn, www.cottoninc.com/CottonPickin/, www.InvasiveSpecies.org/BONAP, and dsslab.cs.gmu.edu/PMIDSS/).

- Because this issue deals with new technologies, it has no endpoint. There are always new information technologies that will provide faster and more comprehensive information sharing. However, the implementation of multi-server database access and XML use will be indicative of acceptance of newer technologies.

Where will the program take place? This will need to be a coordinated effort of federal, university, and industry cooperators working under contract for some lead organization or center. No single entity presently has the total expertise within present invasive species efforts. All groups must agree on some level of standards for key terminology, regardless of technology used. The technical standards for information transfer have already been agreed upon, but not the specifics of our biologically based information.

When will the program take place? Planning can begin in FY2000, assuming the key Federal agencies involved have funding available from FY2000 increase requests in this area. Development should begin in FY2000 or FY 2001 at the latest.

With whom will we work? This area of work requires contact and agreements with individuals already experienced with Internet database and emerging technologies. Much, if not most, of this expertise is located at universities. Although also available in the commercial sector, present commercial costs are generally prohibitive. For these core capabilities to be fully realized, there also needs to be a strong interaction with client groups to identify, organize and prioritize their information needs in terms of specific data, data sources and output format.

What are the potential challenges to success? There are significant language barriers between information technology and biology. There has to be a learning commitment from both groups for real communication. Database ownership and security concerns may be overstated. These issues must be dealt with prior to actual development of specific technology use. There is often resistance to the needed migration to web solutions from older technologies, in spite of demonstrated large fiscal savings. Older IT staff often don't understand the technology and don't want to retrain. There is also often a fear of loss of control.

What resources do we already have? There are already modest resources in use to provide access to invasive species information. In many cases the technology in use is outdated and a reallocation of funds could be required. There are also new funds being made available under IFAFS for possible one-time support, and increases in year 2000 and 2001 targeted for invasive species in many federal agencies.

What additional resources do we need? New information technologies form the cornerstone of information sharing and decision support for science-based responses in invasive species management. Sufficient IT capacity is required to be able to integrate large amounts of spatial, geographical, biological, social and economic data within a risk analysis framework needed for NIS decision support systems. Additionally, there needs to be significant infusion of funding into web-based infrastructure and training. The Executive Order mandates a web-based solution. At least $5 million annually is needed to exploit the new data-sharing technologies (primarily XML and CORBA).

What are the steps to project completion?

1. Reevaluation of older technology to assess where the greatest gains can be achieved.
2. Pilot projects of Web-based programs to compare and contrast competing technologies.
3. Outsourcing for rapid deployment of the technologies.
4. Stakeholder review and priority setting based on that review.
5. Go back to 1 (this will remain an iterative process).

Priority – Establish Stakeholder Technical Committee

Short-term Actions: Establish a stakeholder committee to coordinate technical issues, including:

- XML standards and definitions (see also Issue #3)
- Delineate the unique computer science/information technology R&D requirements for IS- what capacities do we need to help us better collect, manage, share, and apply IS data and information?
- Prioritize these R&D needs (i.e., mobile data collection, interoperability, intelligent search agents)

Expected Outcome: Stakeholder committee established.

Timeline: The action above could be completed within 1 year.

Lead Agencies: Could be led by NSF's Computer and Information Sciences and Engineering Directorate (Digital Government Program??), together with Biological Sciences Directorate.

Resource Requirements: Estimated cost would be less than $100,000 to delineate and prioritize the overall R&D needs for IS.

Other Short-term Actions:
- Support research and development to aid the transition from legacy systems (e.g., Z39.50) to web-based (e.g., XML).
- Support hardware/software development for wireless web-based data entry and retrieval.

Longer-term Actions:
1. Review current "cutting edge" technologies for application in NIS data sharing needs.
2. Develop software for client-specific access to information that is less "intrusive" than cookies but operates in the statelessness of http protocol.
3. Develop efficient technologies for data conversion from non-electronic to electronic.
4. Develop hardware and software for integration of dynamic access and map displays.

ISSUE 5: Integrating Invasive Species Information

In general, it is difficult to effectively overlay and integrate invasive species information with other types of information, including information on the biological and physical environment, as well as socio-economic information. Almost by definition, information on NIS are sparse, incomplete, temporally and spatially limited, and usually uncoordinated across interested and responsible agencies. This limits our ability to provide the full scientific understanding needed for effective prevention, monitoring, management, and control.

Suggested Actions: Provide needed standards and tools to facilitate the integration of invasive species information with other key information sets**.**

What are our desired outcomes? The desired outcome is to develop appropriate standardized methods and formats to collect, report, and make available information on NIS so that information can be compatible and useable with existing resource data sets.

- Resource managers, academia, private industry, federal, state and local government, and the public at large would have the tools necessary to integrate IS data with existing local and national information sets such as habitat, water quality, land use, economics, etc. In addition to linking with environmental/natural resource data sets, there is a need to link/overlay with socio-economic type data sets such as census data, agricultural

statistics, shipping and transportation, etc. This would facilitate assessing the impacts and migration dynamics of IS and aid in developing effective management strategies.

Where will the program take place? Developing standards and appropriate tools such as GIS data sets can be undertaken as a framework component of an overall IS Information Strategy. It could be a work group led by the federal agencies which already have significant investments and activities in invasive species information collection, management and dissemination such as USDA, DOI, EPA, and DOC. An inventory of all relevant national data bases, such as the National Wetlands Inventory, and decisions on how integrating IS info could best be accomplished, would be necessary first steps requiring a federal lead. Additionally, IS is an international problem requiring collaboration with sovereign countries that can only be achieved by federal representation.

When will the effort take place? Planning can begin in FY2000/2001, assuming the key Federal agencies involved have funding available from FY2001 increase requests in this area. Convening the work group could begin in FY2001.

With whom will we work? Federal agencies should take the lead in convening a work group or task force, however, inclusion of a much broader array of stakeholders will be necessary. Input from other partners including State officials, industry, academia, etc. is imperative as they are the final decision makers and implementers. Providing these parties with relevant, useable information is key to managing impacts from IS.

What are the potential challenges to success?

- National data sets are themselves in many different formats and use different standards and methodologies;
- a lack of information regarding IS makes it difficult to ensure how integration with existing data sets could be most effective;
- individual agencies and organizations have many different existing data sets that may not be compatible with one standardized format;
- there are currently no funding resources identified and allocated at the national level (i.e., through one or more of the key Federal agency participants) to support the work needed to design and develop an Information Strategy and convene a work group;
- additional computer/information science R&D may be needed to support particular challenges/requirements for developing the tools necessary to integrate IS information into other national data sets.

What resources do we already have?

- There are currently many national, regional, State and local existing data sets that IS information could be integrated with including the FGDC and National Spatial Data Infrastructure where networks exist and existing standards may be easily adapted;
- many Federal and non-federal agencies and programs (such as the National Estuary Program) are actively attempting to address IS issues and may provide successful examples of incorporating IS info into other data sets for effective prevention and control.

What additional resources do we need? Additional funding is needed to identify how and what is required to develop standards and tools for integrating IS information into existing data sets. Initially, funds for convening an Interagency work group would be necessary followed by soliciting participation from stakeholders around the country who are dealing with IS. Funding for technical support such as computer expertise, software design, GIS, formatting information, etc., would also be needed.

What are the steps to project completion?

1. FY2000 and 2001: establish working group/task force to identify problems associated with IS overlay and integration into existing data sets and appropriate steps to address the problem.
2. 2000 and 2001: identify existing funding and staffing resources available from various government and non-government participants.
3. 2001: identify which National data sets, and/or regional, State, local data sets, that would be most relevant to use as pilots for determining how best to standardize IS information.
4. 2001: identify (and acquire?) additional resources required to develop system (funding, staffing, technological).
5. 2002: present working example of successful format and begin to institutionalize standard and process.

For information about this draft contact:
J. Steve Yaninek
USDA-CSREES
1400 Independence Avenue
Mail Stop 2220
Washington DC, 20250-2220
Tel/Fax (202) 401-6702/1602
Email syaninek@reeusda.gov

ADDITION of June 16, 2000

Priorities – Identifying and Disrupting High-Impact Introduction Pathways

The most cost-effective way to prevent new introductions is often to disrupt the pathways responsible for frequent introductions of multiple species, e.g. ballast water discharge. Emphasis on the pathways, when possible, reduces the need for extensive biological information on multiple species and simplifies risk analysis. Once the major pathways have been identified, highly focused research programs can develop methods to disrupt those pathways and these techniques can be incorporated in NIS prevention campaigns.

Short-term project - Assess known invasions to identify the invasion pathways, intentional or unintentional, that have the potential to cause the most significant ecological and economic impacts.

Timeline: One year; with periodic updates

Resource requirements: $500,000

Expected Outcomes: A list of actual and potential pathways prioritized by predicted economic and environmental impact in the absence of further action.

Lead agencies: Departments of Agriculture, Commerce (NOAA), Interior, and Transportation

Other partners and/or resources: The work should include key federal and state agencies involved in import/export and transportation, representatives from potentially affected industries (e.g. aquarium trade, shipping, produce import trade), and academic researchers.

Long-term project – Develop Rapid Detection Methods: Once high-priority pathways are identified, we need to be able to screen them rapidly for the presence of potential invading organisms. These techniques could include genetic probes, sensory technology (acoustical, x-ray, remote sensing), species-specific attractants (such as UV light or pheromones for insect) and traps, and survey protocols to allow the rapid detection and identification of NIS in both terrestrial and aquatic systems.

Timeline: Five years

Resource requirements: $2 M per year

Expected Outcomes: Products would include, for example, rapid methods to screen a wide range of imports (e.g. foods, lumber and lumber products, live plants and animals, and other commercial products) for NIS at their point of entrance and at ports in their country of origin.

Lead agencies: According to the pathway of concern.

Other partners and/or resources: Federal labs, industry, academic institutions and partnering international institutions.

Long-term project - Develop cost-effective measures to disrupt introduction pathways: Efforts would be concentrated on the high-priority pathways identified through the assessment activity. Measures would include as appropriate technology, policy, and public education .

Timeline: Five years

Resource requirements: $5 M per year

Expected Outcomes: Cost-efficient measures that would significantly reduce the impact due to a given pathway of NIS invasion. Technology transfer and public education materials as appropriate for a given pathway.

Lead agencies: According to the pathway of concern.

Other partners and/or resources: Federal labs, industry, academic institutions and partnering international institutions.